NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 68-FM-56

March 5, 1968

COMPARISON BETWEEN APOLLO REFERENCE MISSION PROGRAM (ARMO5) AND HIGH SPEED INTEGRATION PROGRAM (PNGSAG)

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(NASA-TM-X-69425) COMPARISON BETWEEN APOLLO REFERENCE MISSION PROGRAM (ARMO5) AND HIGH-SPEED INTEGRATION PROGRAM (PNGSAG) (NASA) 8 p

N74-70900

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PROJECT APOLLO

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SUMMARY

The purpose of this study was to determine if the High-Speed Integration Program (PNGSAG) is significantly faster than a precision integrated program (ARM05), and if so, how much accuracy is sacrificed for this speed. Since the LOI targeting processor would be one of the primary users of the High-Speed Integration Program, the test cases were chosen to be lunar orbit insertion maneuvers. Lambert and external ΔV were both considered as guidance schemes for these LOI test cases. The results of the study show that PNGSAG is from 2.5 to 7 times faster than ARM05 depending on the guidance and size of integration step used. Also, the lunar parking orbit achieved with PNGSAG was off only hundredths of a mile in apogee and perigee altitudes and thousandths of a degree in right ascension and inclination

INTRODUCTION

There are several instances in mission planning and design for which a fast and reasonably accurate method of integrating a state vector through a simulated burn is highly desirable, if not necessary. One of the best examples of these instances is the RTCC LOI Targeting Processor. During its use, many simulated LOI maneuvers must be integrated within a short time to insure that the desired lunar orbit will be achieved within the allowable fuel budget. Aborts are another area in which a large number of integrated burns must be scanned in a short time to determine an acceptable solution.

This study was initiated to determine the speed and accuracy of the High-Speed Integration Program (PNGSAG). This program is a stripped-down version of the Guidance Analysis High-Speed Program (GAHSP) which uses analytic schemes for simulating vehicle attitude time histories and sensed velocity increments (integrals of thrust acceleration over a given time step) used to integrate (in a simple numerical form) the total acceleration vectors. A more detailed description of the integration procedure and method of updating the state vector may be found in reference 1.

The precision integrated trajectory program ARM05 was chosen to compare with PNGSAG because of its wide use as a reference trajectory program. A more detailed description of ARM05 and its uses may be found in reference 2.

A typical lunar orbit insertion maneuver was chosen for the test cases; both Lambert and external ΔV were used for guidance. Several different integration step sizes were used with each type guidance in each program, and the resulting computer runs were timed and the end conditions noted. The results of these timed runs are shown in table I and figure 1.

SYMBOLS

LOI	lunar orbit insertion
RTCC	Real-Time Computer Complex
ARM05	Apollo Reference Mission Program
PNGSAG	High-Speed Integration Progarm
GAHSP	Guidance Analysis High-Speed Program
T_{BURN}	burn time of simulated LOI maneuver, sec
$T_{COMPUTE}$	integration step size, sec
T_{RUN}	run time of program, sec
r_a	radius of apogee, n. mi.
r_p	radius of perigee, n. mi.
INCS	selenocentric inclination, deg
RANS	selenocentric right ascension of ascending node, deg

ANALYSIS

The LOI maneuver chosen as the test case for this study made a 10° plane change and burned out into a 60- by 170-n. mi. lunar parking orbit which was contained in the lunar equatorial plane. The target conditions for both Lambert and external ΔV guidance which would achieve the above mentioned orbit from a given approach trajectory were obtained from the generalized iteration routine which is a part of the ARM05 program. After these target conditions were obtained, itegration step sizes of 2, 10, and 20 seconds were chosen, and the simulated LOI maneuvers were run on both ARM05 and PNGSAG. These runs were timed by calling the computer clock as soon as the LOI simulation was completed. The end conditions of each of these runs along with the timings are tabulated in table I.

RESULTS

Figure 1 compares the run times of ARM05 and PNGSAG using both Lambert and external ΔV guidance for different size integration steps. It should be noted that there is a gradual increase in run time advantage for PNGSAG as the integration step sizes become larger. For example, with a 2-second integration step size and using Lambert guidance, PNGSAG runs approximately 2.5 times faster than ARM05. But when this integration step size is increased to 20 seconds, PNGSAG then runs approximately 3.6 times faster than ARM05. Using the same example, but with external ΔV guidance instead of Lambert, the run time advantage for PNGSAG increases from 5.3 times faster with 2-second step sizes to 7.0 times faster with 20-second step sizes.

Table I shows the end conditions achieved with both ARM05 and PNGSAG using different guidance schemes and integration step sizes. Differences between ARM05 and PNGSAG varied from 0.002 to 0.14 n. mi., respectively, for radius at apogee and from 0.004 to 0.04 n. mi., respectively, for radius at perigee. Differences in inclination and right ascension varied from 0.00003° to 0.0034° and from 0.00025° to 0.0023°, respectively.

CONCLUSIONS

It may be concluded from the above results that the High-Speed Integration Program is significantly faster than ARM05. This running time advantage varies from approximately 2.5 to 7 times faster than ARM05, depending on the guidance and integration step size used. Along with this speed advantage of PNGSAG, there does not seem to be a great deal of accuracy loss. The usual variations encountered in apogee and perigee radii were in the hundredths of a mile and the inclination and right ascension variations generally were in the thousandths or ten thousandths of a degree.

With this speed and accuracy, the High-Speed Integration Program would seem to be a likely candidate for use in any situation where a large number of vehicle burns need to be simulated in a short period of time.

TABLE I.- COMPARISON OF PNGSAG AND ARM05

Guidance	Program	$T_{COMPUTE}$, sec	Total number of integration steps	T_{RUN}, sec	T_{BURN}, sec	r_a, n. mi.	r_p, n. mi.	INCS, deg	RANS, deg
Lambert	ARM05	2.	191	10.795	381.465	1108.4934	998.49348	157.99435	178.74278
Lambert	PNGSAG	2.	191	4.299	381.468	1108.4781	998.50532	157.99432	178.74332
Lambert	ARM05	10.	39	2.710	381.461	1108.5091	998.47582	157.99509	178.74961
Lambert	PNGSAG	10.	39	0.911	381.468	1108.5112	998.49910	157.99432	178.75188
Lambert	ARM05	20.	20	1.782	381.464	1108.5217	998.46532	157.99607	178.75865
Lambert	PNGSAG	20.	20	0.493	381.475	1108.6601	998.50990	157.99270	178.76314
External ΔV	ARM05	2.	191	7.918	381.474	1108.5393	998.49499	157.99452	178.74279
External ΔV	PNGSAG	2.	191	1.504	381.477	1108.4875	998.49917	157.99423	178.74304
External ΔV	ARM05	10.	39	2.077	381.474	1108.5368	998.49499	157.99450	178.74279
External ΔV	PNGSAG	10.	39	0.320	381.479	1108.4713	998.50152	157.99411	178.74327
External ΔV	ARM05	20.	20	1.192	381.474	1108.5360	998.49501	157.99449	178.74280
External ΔV	PNGSAG	20.	20	0.170	381.483	1108.4701	998.50640	157.99417	178.74366

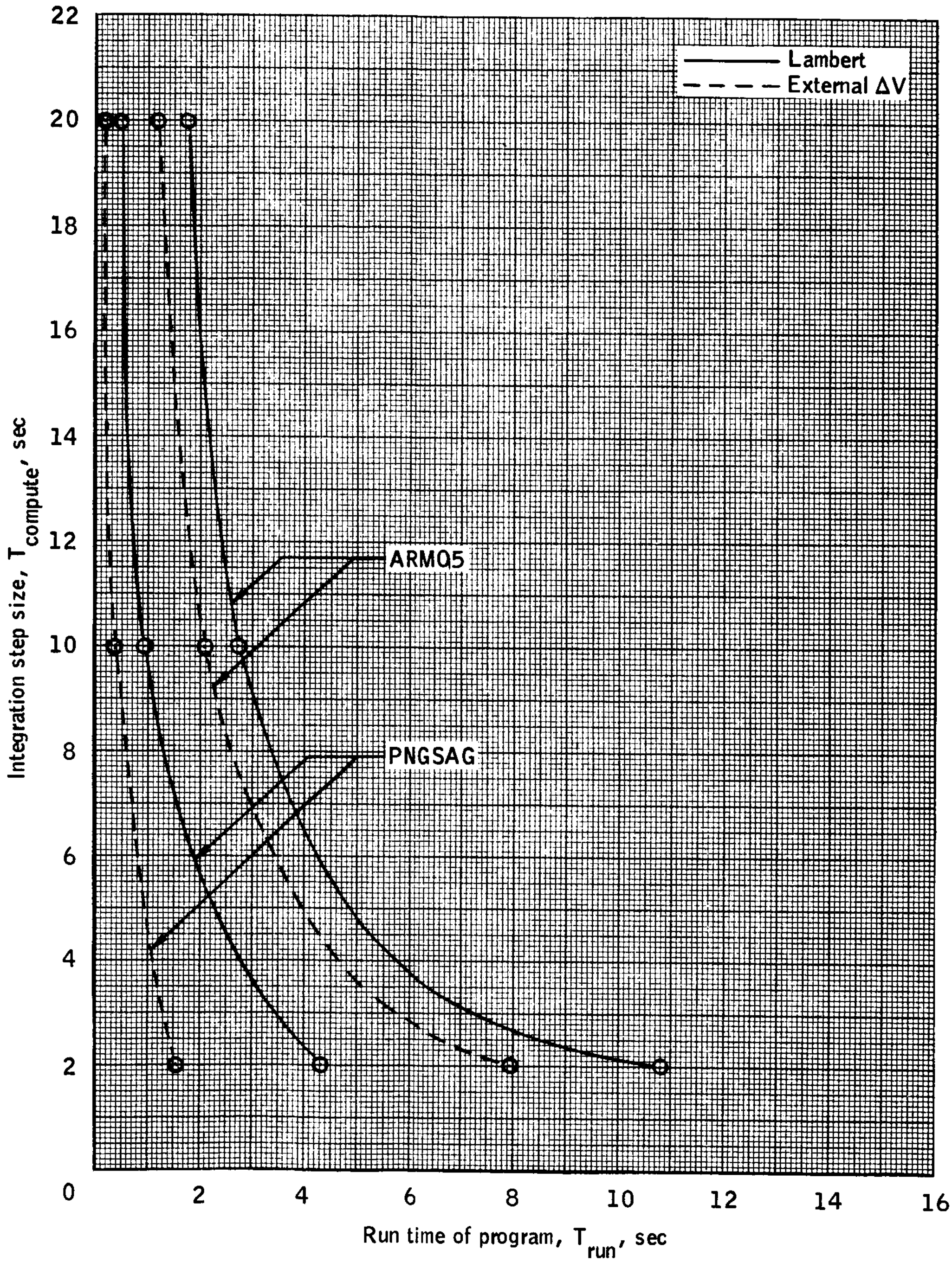

Figure 1.- Run time comparison between ARM05 and PNGSAG.

REFERENCES

1. Burton, N. R.: GAHS Program Description and Users' Guide. TRW Note No. 67-FMT-552, September 19, 1967.

2. Miller, J. J.: Apollo Reference Mission Program Version ARM05. NAS 9-4810, June 26, 1967.